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This study describes the four main demersal fish assemblages identified along the continental shelf and slope (30–800 m depth) of the northern Alboran Sea (western Mediterranean), based on the analysis of the MEDITS (International bottom trawl survey in the Mediterranean) 12-year data series. We collected 186 fish species belonging to three classes, 24 orders and 69 families. Taxonomically, the order Perciformes was the most diverse, represented by 18 families and 58 species. Each assemblage had particular characteristics of abundance, biomass, mean fish weight and species richness. The geographical differences associated with the distribution of some species occurred within shelf assemblages. The middle slope was characterised by the highest similarity between samples, probably due to its lower environmental variability compared to that of the other assemblages.

Keywords: ichthyofauna; demersal species; Alboran Sea; assemblages; spatial distribution; species richness

Introduction

The Alboran Sea (southwestern Mediterranean) is a transition region between the Mediterranean basin and the Atlantic Ocean. Its very complex hydrology, with Atlantic surface currents and deep Mediterranean waters, different scale gyres, high activity fronts and upwelling areas, creates a significant regionalisation and a marked heterogeneity in biological diversity (Rodríguez 2011). The remarkable pecularities in the temperature and salinity of these water masses flowing through the Strait of Gibraltar are seemingly important factors that affect communities and particularly species that may or may not be tolerant to these environmental variables (euryhaline, stenohaline, eurythermal and stenothermal species). In addition, the Alboran Sea, together with the Gulf of Lion and the mouth of different rivers, is amongst the western Mediterranean areas with the highest rates of primary production (Vargas-Yáñez et al. 2010; Rodríguez 2011). Moreover, the geographical location of the Alboran Sea promotes the confluence of fauna from different biogeographic regions, resulting in relatively high biodiversity compared with other Mediterranean areas (Gaertner et al. 2007; Templado 2011; Urra et al. 2011; Sabelli and Taviani 2014). The combination of all these features in the Alboran Sea justifies the scientific interest in furthering knowledge of the fauna and flora of such a remarkable place in southern Europe, in order to document the rarity or absence of certain Mediterranean

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endemisms (Pérès and Picard 1964) and their relationship with Atlantic species (tropical and boreal).

Fish communities have their own features, such as longevity, larger size and mobility, compared with other marine animals, which allow them to play an important role in ecosystems, influencing the flow of energy and transport of substances and materials. These characteristics discriminate them from other components of marine ecosystems and allow fish to be used as indicators of different environmental scenarios. In addition, fish can be also considered proxies to assess changes in water. Moreover, this role of fish as indicators is related to a spatiotemporal scale superior to other faunistic groups (Sostoa et al. 2005). Demersal resources in the Alboran Sea consist of a wide variety of fish species, many of which are considered target species of economic interest (García et al. 2012).

Despite the importance of ichthyofauna in marine systems, data on the distribution of the Alboran Sea demersal fish species and communities are very scarce compared with data from other Mediterranean areas. Previous studies mainly concern the continental shelf area and are related to infralitoral fish assemblages (Reina-Hervás 1987), are updates of ichthyofaunal inventories for the Iberian Western Mediterranean (Lloris et al. 2000), or give information on a large-scale basis of the demersal fish assemblages in the northwestern Mediterranean Sea (including the Alboran Sea) (Gaertner et al. 2005, 2007). Abad et al. (2007) analysed the composition and abundance of fauna caught in the Alboran Sea by commercial trawlers between 50 and 640 m depth over 1 year, providing information on demersal and epibenthic assemblages.

The paucity of ichthyofaunal studies in the Alboran Sea contrasts with the extensive knowledge on this issue for other areas of the Spanish Mediterranean coastline (Stefanescu 1991; Stefanescu et al. 1993, 1994; Massutí et al. 1996, 2004; Moranta et al. 1998, 2007, 2008; Demestre et al. 2000; Cartes and Carrassón 2004; D'Onghia et al. 2004; Massutí and Reñones 2005; García-Rodríguez et al. 2011; Papiol et al. 2012; Fanelli et al. 2013) or of other countries located in the Mediterranean basin (Tserpes et al. 1999; Ungaro et al. 1999; Kallianiotis et al. 2000, 2004; Labropoulou and Papaconstantinou 2000; Blanchard 2001; Colloca et al. 2003; D'Onghia et al. 2003; Madurell et al. 2004; Mérigot et al. 2007; Dimech et al. 2008; Keskin et al. 2011).

The aim of this study is to provide an updated ichthyofaunal inventory for the Alboran Sea and to analyse the bathymetric and geographical distribution patterns along the continental shelf and slope of this Mediterranean area. The study is based on the information gathered over 12 years from 351 sampling stations. We also compared bathymetric zonation patterns with those of other Mediterranean areas in order to provide further evidence of the uniqueness of the Alboran Sea.

Materials and methods

Faunistic data were compiled from the 12-year time database of MEDITS (International bottom trawl survey in the Mediterranean) surveys carried out along the Iberian Mediterranean coast by the Instituto Español de Oceanografía (Spain) on board the research vessel *Cornide de Saavedra*. This work is based on samples taken from Estepona to Cabo de Gata (Figure 1) between 1994 and 2005, at depths of 30–800 m.

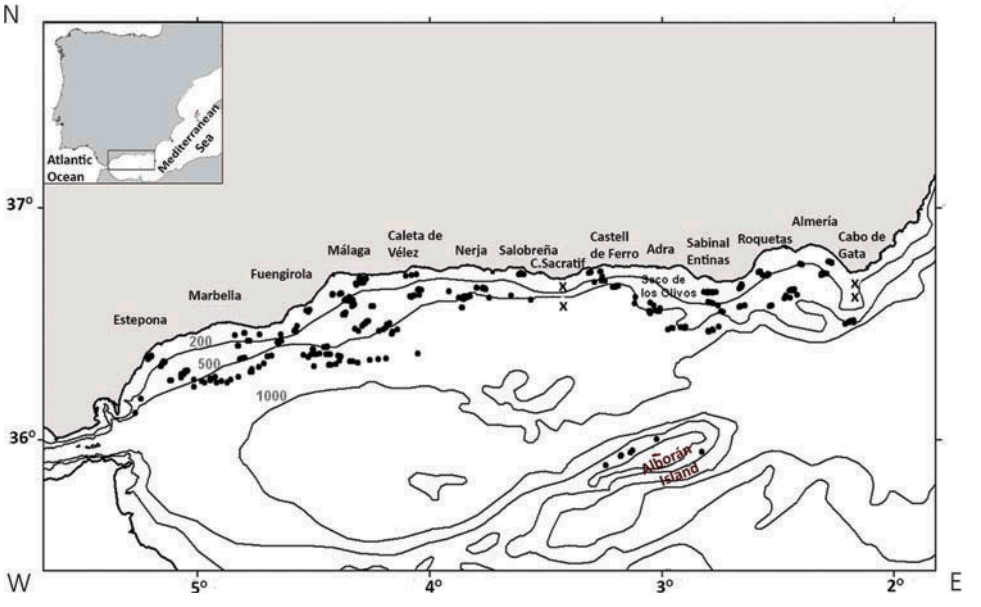


Figure 1. Map of the study area throughout the northern Alboran Sea showing the haul stations from the MEDITS survey series, from 1994 to 2005 (black points) and sampled stations from RADMED (Radiales del Mediterráneo) programme (black crosses).

According to the MEDITS standardised protocol (Bertrand et al. 2000, 2002), the surveys took place every year in spring (Table 1). Sampling stations were chosen by applying a stratified random sampling scheme using depth as the stratification parameter to define the following bathymetric limits: 30, 50, 100, 200, 500 and 800 m. The haul duration was 30 minutes at depths lower than 200 m and 60 minutes at greater depths. The gear used for sampling was a bottom trawl gear (GOC-73) designed for experimental purposes and with a codend mesh size of 20 mm, average vertical opening of 2.5 m and average horizontal opening of 18.5 m. Samples were collected at a mean towing speed of 3 knots.

For each sampling station, haul specimens were sorted, identified, counted and weighed on board. The characterisation of taxa was based on Nelson (1994), while identification and species nomenclature were completed according to various sources, including Whitehead et al. (1984–1986), Lloris et al. (2003) and Froese and Pauly (2008).

For each haul, the numbers and weights of individuals per species were standardised to 1 hour towing in order to calculate both species abundance (number of individuals per 1 hour towing, [ind h^{-1}]) and biomass (g h^{-1}). The mean fish weight was obtained for each species by dividing the biomass by the number of individuals. The frequency of occurrence of each species (F) was calculated as the ratio between the number of occurrences of a species and the total number of hauls, and expressed as a percentage (%).

In order to identify species assemblages, we applied ordination methods using fish species abundance and biomass per haul matrices. Prior to analysis, all data were logarithmically transformed using log (x + 1) to minimise the weighting of extreme

Table 1. Trawl surveys conducted during the study period, and number of hauls.

Survey	Initial date	Final date	Number of hauls
MEDITS_ES 94	28 May 1994	4 June 1994	25
MEDITS_ES 95	22 April 1995	27 April 1995	22
MEDITS_ES 96	2 May 1996	8 May 1996	29
MEDITS_ES 97	10 May 1997	17 May 1997	26
MEDITS_ES 98	3 May 1998	12 May 1998	25
MEDITS_ES 99	4 May 1999	11 May 1999	30
MEDITS_ES 00	22 May 2000	30 May 2000	33
MEDITS_ES 01	12 May 2001	20 May 2001	29
MEDITS_ES 02	11 May 2002	19 May 2002	33
MEDITS_ES 03	26 April 2003	1 May 2003	37
	24 May 2003	26 May 2003	
MEDITS_ES 04	6 May 2004	11 May 2004	33
	2 June 2004	3 June 2004	
MEDITS_ES 05	9 May 2005	14 May 2005	29
	6 June 2005	7 June 2005	
TOTAL			**351**

abundance or biomass values of certain species (Clarke and Warwick 2001). The similarity matrix obtained from species abundance and biomass data based on the Bray–Curtis similarity coefficient (Bray and Curtis 1957) was ordinated using Shepard (1962) and Kruskal's (1964) non-metric multidimensional scaling (nMDS) analysis.

A permutational multivariate analysis of variance (PERMANOVA; Anderson 2001) was performed using one-factor design. The PERMANOVA evaluated the statistical significance of depth-related groups identified by nMDS analysis. Significance was set at $p = 0.01$ and p-values were obtained using 9999 permutations.

The percentage of similarity routine (SIMPER) served to analyse the ichthyofaunal assemblages by identifying the species responsible for the differences between groups and those that characterise each group.

Species rarefaction curves, which represent the number of species accumulated in an inventory correlated with the actual sampling effort (Gotelli and Colwell 2001; Jiménez-Valverde 2003), were used to compare the species richness values of each fish assemblage.

For each fish assemblage identified in the bathymetric comparisons, we analysed its longitudinal variation in the study area. The following geographical locations were identified (from west to east) in the northern sector of the Alboran Sea: Estepona (ES), Marbella (MR), Fuengirola (FU), Malaga (ML), Caleta de Velez (CL), Nerja (N), Salobreña (S), Castell de Ferro (FE), Alboran Island (I), Adra (AD), Seco de los Olivos (O), Sabinal-Punta Entinas (EN), Roquetas (R), Almeria (AL) and Cabo de Gata (G) (Figure 1).

The similarity between samples according to their geographical location was tested with an nMDS using the similarity matrix data obtained from species abundance data.

All these analyses were performed using the statistical package PRIMER v. 6 and PERMANOVA+ (Anderson 2001; Clarke and Gorley 2006).

To compare the mean values of the variables analysed (abundance, biomass and mean fish weight of each species) across the fish assemblages identified, we used a non-parametric Kruskal–Wallis test (Kruskal and Wallis 1952). This test is made when the requirements to perform a parametric analysis of variance (ANOVA) are not met.

Results

Ichthyofaunal composition

We found a total of three fish classes (Myxini, Chondrichthyes and Osteichthyes) represented by 24 orders, 69 families and 186 species in the different samples.

Taxonomically, the order Perciformes was the most diverse, with 18 families and 58 species (Table 2). In terms of abundance, the order Zeiformes was dominant (25%), followed by Clupeiformes (23%). The greatest biomass values were observed for the order Perciformes (31%), followed by Carcharhiniformes (23%) (Table 2).

Table 2. Number of families, number of species, abundance (ind h^{-1}) and biomass (g h^{-1}) of each fish order collected in the MEDITS survey series between 1994 and 2005. Values in brackets are percentages (%).

Order	No. families	No. species	Abundance	Biomass
Myxiniformes	1 (1.4)	1 (0.5)	0.03 (< 0.1)	0.06 (< 0.1)
Chimaeriformes	1 (1.4)	1 (0.5)	3 (0.1)	1953 (2)
Carcharhiniformes	2 (2.9)	5 (2.7)	118 (3)	20,688 (23)
Hexanchiformes	1 (1.4)	1 (0.5)	0.06 (< 0.1)	20 (< 0.1)
Squaliformes	3 (4.3)	5 (2.7)	33 (0.3)	2391 (3)
Rajiformes	2 (2.9)	7 (3.8)	1 (< 0.1)	669 (0.7)
Albuliformes	1 (1.4)	1 (0.5)	1 (< 0.1)	17 (< 0.1)
Anguilliformes	5 (7.2)	9 (4.8)	8 (0.2)	1151 (1)
Clupeiformes	2 (2.9)	4 (2.2)	1031 (23)	5393 (6)
Osmeriformes	2 (2.9)	3 (1.6)	8.3 (0.2)	1020 (1)
Stomiiformes	4 (5.8)	10 (5.4)	424 (9)	419 (0.5)
Aulopiformes	3 (4.3)	4 (2.2)	0.3 (< 0.1)	2 (< 0.1)
Myctophiformes	1 (1.4)	12 (6.5)	96 (2)	313 (0.3)
Ophidiiformes	3 (4.3)	7 (3.8)	0.4 (< 0.1)	7 (< 0.1)
Gadiformes	5 (7.2)	14 (7.5)	804 (18)	17,114 (19)
Lophiiformes	1 (1.4)	2 (1.1)	2 (< 0.1)	1399 (2)
Mugiliformes	1 (1.4)	1 (0.5)	0.02 (< 0.1)	5 (< 0.1)
Beryciformes	1 (1.4)	1 (0.5)	58 (1)	1127 (1)
Zeiformes	2 (2.9)	3 (1.6)	1129 (25)	6006 (7)
Gasterosteiformes	1 (1.4)	1 (0.5)	16 (0.4)	100 (0.1)
Scorpaeniformes	2 (2.9)	15 (8.1)	65 (1)	2038 (2)
Perciformes	18 (26.0)	58 (31.2)	684 (15)	27,695 (31)
Pleuronectiformes	5 (7.2)	19 (10.2)	27 (1)	291 (0.3)
Tetraodontiformes	2 (2.9)	2 (1.1)	0.06 (< 0.1)	153 (0.2)
TOTAL	**69 (100%)**	**186 (100%)**	**4509 (100%)**	**89,971 (100%)**

In relation to the number of species, Rajiiformes and Squaliformes were the most represented among Chondrichthyes orders, with seven and five species, respectively. Osteichthyes were mostly represented by the order Perciformes (58 species), Pleuronectiformes (19 species), Gadiformes (14 species) and Anguiliformes (nine species) (Table 2).

The species with the highest frequency of occurrence in the Chondrichthyes class were *Galeus melastomus* (50%), *Scyliorhinus canicula* (44%), *Etmopterus spinax* (41%) and *Chimaera monstrosa* (33%). Among Osteichthyes, the most frequent species were *Helicolenus dactylopterus* (66%), *Conger conger* (62%), *Phycis blennoides* (61%), *Lophius budegassa* (54%) and *Hoplostethus mediterraneus* (53%) (Table 3).

The most abundant species in the Chondrichthyes class were *G. melastomus* (107.2 ind h^{-1}), *E. spinax* (12.5 ind h^{-1}) and *S. canicula* (7.6 ind·h^{-1}), and, among Osteichthyes, *Capros aper* (1129.1 ind h^{-1}), *Sardina pilchardus* (834 ind h^{-1}) and *Micromesistius poutassou* (456.3 ind h^{-1}).

In terms of biomass, *G. melastomus* (18,436.1 g h^{-1}), *C. monstrosa* (1953.9 g h^{-1}) and *S. canicula* (1630.7 g h^{-1}) were the dominant Chondrichthyes, and *Pagellus acarne* (13,560.2 g h^{-1}), *M. poutassou* (6018.7 g h^{-1}) and *C. aper* (5935.1 g h^{-1}) were the dominant Osteichthyes (Table 3).

Identified assemblages

nMDS analyses based on both abundance and biomass data showed an ordination structuring the 351 sampled hauls into four groups, basically in relation to depth. These groups corresponded to hauls carried out between depths of 30 and 100 m (inner shelf, IS), 100 and 200 m (outer shelf, OS), 200 and 500 m (upper slope, US), and 500 and 800 m (middle slope, MS) (Figure 2).

PERMANOVA results indicated significant values for these depth range groups ($p < 0.01$; Table 4).

SIMPER analyses on species abundance data highlighted the mean similarity within each group and those species that contributed to the mean similarity (Table 5a). *Pagellus acarne, Boops boops* and *Serranus hepatus* contributed 60% of the similarity within the IS assemblage. In the OS assemblage, *C. aper* contributed 60% of the similarity between samples. In the US assemblage, *Coelorhynchus coelorhynchus, H. mediterraneus* and *P. blennoides* made the largest contribution (56%) to similarity. In the MS assemblage, *Nezumia aequalis* and *G. melastomus* contributed equally to the similarity within this group (36 and 35%, respectively) and were the most characteristic species. The MS assemblage was characterised by the highest mean similarity between samples, with 47.21 versus 15.31 of the IS, 15.26 of the OS and 21.73 of the US assemblages.

Comparison between IS and OS shows that the species contributing most to dissimilarity is *C. aper* followed by *Maurolicus muelleri* and *P. acarne. Capros aper* and *M. muelleri* are more abundant in OS while *P. acarne* is more abundant in IS. Between OS and US, *C. aper*, *M. poutassou* and *M. muelleri* are the species accumulating the highest % dissimilarity. All of them are more abundant in OS. *G. melastomus* and *N. aequalis* contribute much to the dissimilarity between US and MS with highest values in the last one. *Coelorhynchus coelorhynchus* and *Gadiculus argenteus* are more abundant in the US group. The highest values of average dissimilarity are between OS and US, and the lowest are between US and MS (Table 5b).

Table 3. Fish species collected in the MEDITS survey series showing data of frequency of occurrence (F), abundance (ind h^{-1} ± standard deviation, SD) and abundance (%), biomass (g h^{-1} ± SD), biomass (%). The species are listed alphabetically.

	F (%)	Abundance ± SD	Abundance (%)	Biomass ± SD	Biomass (%)
Alepocephalus rostratus Risso, 1820	13.7	8.28 ± 60.63	0.185	1019.34 ± 7792.35	1.133
Alosa fallax fallax (Lacépède, 1803)	0.6	0.01 ± 0.15	< 0.001	5.49 ± 76.93	0.006
Anguilla anguilla (Linnaeus, 1758)	0.6	0.01 ± 0.12	< 0.001	4.13 ± 73.23	0.005
Anthias anthias (Linnaeus, 1758)	2.6	1.38 ± 18.45	0.031	29.38 ± 345.43	0.033
Antonogadus megalokynodon (Kolombatovic, 1894)	33	1.89 ± 6.16	0.042	9.27 ± 27.65	0.01
Aphia minuta mediterranea De Buen, 1931	4.8	17.68 ± 231.34	0.394	3.05 ± 37.05	0.003
Argentina sphyraena Linnaeus, 1758	2	0.05 ± 0.36	0.001	0.51 ± 3.96	0.001
Argyropelecus hemigymnus Cocco, 1829	38.5	2.31 ± 6.21	0.051	1.35 ± 3.12	0.002
Arnoglossus imperialis (Rafinesque, 1810)	10	4.17 ± 39.09	0.093	75.29 ± 754.3	0.084
Arnoglossus laterna (Walbaum, 1972)	19.4	4.65 ± 21.47	0.104	29.09 ± 130.91	0.032
Arnoglossus rueppelli (Cocco, 1844)	4.8	0.17 ± 1.12	0.004	2.3 ± 16.64	0.003
Arnoglossus thori Kyle, 1913	19.1	9.14 ± 35.23	0.204	52.57 ± 205.23	0.058
Aspitrigla cuculus (Linnaeus, 1758)	2	0.07 ± 0.54	0.002	6.54 ± 64.15	0.007
Aspitrigla obscura (Linnaeus, 1764)	1.1	0.03 ± 0.28	0.001	2.72 ± 29.54	0.003
Bathophilus nigerrimus Giglioli, 1884	0.6	0.01 ± 0.08	< 0.001	0.05 ± 0.74	< 0.001
Bathysolea profundicola (Vaillant, 1888)	17.4	1.2 ± 8.83	0.027	19.32 ± 132.48	0.021
Bellottia apoda Giglioli, 1883	0.3	< 0.01 ± 0.05	< 0.001	0.01 ± 0.11	< 0.001
Benthocometes robustus (Goode & Bean, 1886)	0.6	0.01 ± 0.08	< 0.001	0.06 ± 0.86	< 0.001
Benthosema glaciale (Reinhardt, 1837)	12.5	21.68 ± 315.65	0.483	17.55 ± 252.87	0.02
Blennius ocellaris Linnaeus, 1758	13.1	0.6 ± 2.37	0.013	12.92 ± 54.32	0.014
*Boops boops (*Linnaeus, 1758)	28.2	71.31 ± 325.08	1.589	3425.33 ± 12,116.34	3.807
Bothus podas podas (Delaroche, 1809)	0.3	0.01 ± 0.21	< 0.001	0.11 ± 2.14	< 0.001
Callionymus lyra Linnaeus, 1758	0.6	0.01 ± 0.15	< 0.001	0.35 ± 4.6	< 0.001
Callionymus maculatus Rafinesque-Schmaltz, 1810	23.4	8.53 ± 37.17	0.19	31.17 ± 132.2	0.035
Callionymus pusillus Delaroche, 1809	0.3	0.03 ± 0.64	0.001	0.13 ± 2.35	< 0.001
Callionymus rissoi Le Sueur, 1814	0.6	0.02 ± 0.24	< 0.001	0.06 ± 0.88	< 0.001
Capros aper (Linnaeus, 1758)	42.7	1129.07 ± 7275.85	25.152	5935.07 ± 50,173.59	6.596

(*Continued*)

Table 3. (Continued).

	F (%)	Abundance ± SD	Abundance (%)	Biomass ± SD	Biomass (%)
Caranx ronchus E. Geoffroy Saint-Hilaire, 1817	0.6	0.02 ± 0.24	< 0.001	6.25 ± 88.71	0.007
Carapus acus (Brünnich, 1768)	2.8	0.08 ± 0.52	0.002	0.58 ± 4.48	0.001
*Cataetyx alleni (*Byrne, 1906)	0.3	< 0.01 ± 0.05	< 0.001	0.01 ± 0.16	< 0.001
Centrolophus niger (Gmelin, 1788)	2	0.02 ± 0.14	< 0.001	58.59 ± 609.76	0.065
Centrophorus uyato (Rafinesque, 1810)	5.7	0.1 ± 0.47	0.002	354.64 ± 1716.83	0.394
Cepola rubescens Linnaeus, 1766	18.5	16.45 ± 64.53	0.366	610.47 ± 2347.5	0.678
Ceratoscopelus maderensis (Lowe, 1839)	29.9	10.35 ± 74.91	0.231	13.17 ± 91.95	0.015
Chauliodus sloani Schneider, 1801	15.1	0.26 ± 0.77	0.006	6.1 ± 18.99	0.007
*Chelon labrosus (*Risso, 1826)	0.3	0.01 ± 0.11	< 0.001	5.37 ± 100.67	0.006
Chimaera monstrosa Linnaeus, 1758	33.9	2.79 ± 6.85	0.062	1953.93 ± 5208.77	2.172
Chlorophthalmus agassizi Bonaparte, 1840	6.8	0.15 ± 0.73	0.003	0.79 ± 3.43	0.001
Citharus linguatula (Linnaeus, 1758)	4.3	0.2 ± 1.71	0.004	18.1 ± 177.05	0.02
Coelorhynchus coelorhynchus (Risso, 1810)	45	55.44 ± 157.76	1.235	820.39 ± 1730.98	0.912
Conger conger ([Artedi, 1738] Linnaeus, 1758)	61.5	2.77 ± 5.23	0.062	805.86 ± 2051.71	0.896
Crystallogobius linearis (von Düben y Koren, 1846)	1.7	1.37 ± 19.77	0.03	0.24 ± 3.45	< 0.001
Cyclothone braueri Jespersen y Taning, 1926	1.1	0.1 ± 1.08	0.002	0.02 ± 0.21	< 0.001
Cyclothone pygmaea Jepersen y Taning, 1926	1.1	0.03 ± 0.32	0.001	0.01 ± 0.11	< 0.001
Dalatias licha (Bonnaterre, 1788)	12	0.24 ± 0.89	0.005	892.57 ± 3870.96	0.992
Deltentosteus quadrimaculatus (Valenciennes, 1837)	15.1	2.52 ± 11.35	0.056	7.51 ± 31.29	0.008
Dentex dentex (Linnaeus, 1758)	0.3	0.01 ± 0.11	< 0.001	18.8 ± 352.28	0.021
Dentex maroccanus Valenciennes, 1830	0.9	0.02 ± 0.18	< 0.001	3.52 ± 49.61	0.004
Diaphus holti Taning, 1918	3.7	0.05 ± 0.3	0.001	0.08 ± 0.47	< 0.001
Dicologoglossa cuneata ([de la Pylaie] Moreau, 1881)	0.9	0.01 ± 0.16	< 0.001	1.31 ± 17.99	0.001
Diplecogaster bimaculata (Bonnaterre, 1788)	1.1	0.03 ± 0.28	0.001	0.02 ± 0.21	< 0.001
Diplodus annularis (Linnaeus, 1758)	0.3	0.01 ± 0.21	< 0.001	0.89 ± 16.76	0.001
Diplodus cervinus cervinus (Lowe, 1841)	0.3	0.03 ± 0.64	0.001	35.9 ± 672.54	0.04
Diplodus puntazzo (Cetti, 1777)	0.3	0.01 ± 0.11	< 0.001	2.37 ± 44.41	0.003
Diplodus vulgaris (E.Geoffroy Saint-Hilaire, 1817)	5.1	1.28 ± 11.03	0.028	226.23 ± 1877.92	0.251

(*Continued*)

Table 3. (Continued).

Echelus myrus (Linnaeus, 1758)	10.5	0.81 ± 3.66	0.018	136.96 ± 634.07	0.152
Echiodon dentatus (Cuvier, 1829)	0.3	< 0.01 ± 0.05	< 0.001	0.01 ± 0.16	< 0.001
Electrona rissoi (Cocco, 1829)	2.6	0.06 ± 0.63	0.001	0.12 ± 1.06	< 0.001
Engraulis encrasicolus (Linnaeus, 1758)	4	197.43 ± 2877.63	4.398	1461.83 ± 19,182.64	1.625
Epigonus denticulatus Dieuzeide, 1950	34.2	8.61 ± 23.07	0.192	37.14 ± 250.55	0.041
Epigonus telescopus (Risso, 1810)	7.1	0.57 ± 4.85	0.013	21.27 ± 140.42	0.024
Etmopterus spinax (Linnaeus, 1758)	41	12.47 ± 32.98	0.278	1016.01 ± 2583.46	1.129
Evermannella balbo (Risso, 1820)	2.8	0.03 ± 0.21	0.001	0.21 ± 1.39	< 0.001
Facciolella oxyrhyncha (Bellotti, 1883)	0.6	0.01 ± 0.12	< 0.001	0.19 ± 2.57	< 0.001
Gadella maraldi (Risso, 1810)	0.3	< 0.01 ± 0.05	< 0.001	0 ± 0.05	< 0.001
Gadiculus argenteus argenteus (Guichenot, 1850)	31.6	131.83 ± 531.39	2.937	642.58 ± 2441.6	0.714
Galeorhinus galeus (Linnaeus, 1758)	1.7	0.02 ± 0.16	< 0.001	234.86 ± 1860.54	0.261
Galeus atlanticus (Vaillant, 1888)	8.8	2.93 ± 15.52	0.065	361.42 ± 1899.31	0.402
Galeus melastomus Rafinesque, 1810	50.4	107.21 ± 193.23	2.388	18,436.11 ± 35,655.09	20.49
Glossanodon leioglossus (Valenciennes, 1848)	1.7	0.03 ± 0.24	0.001	0.05 ± 0.48	< 0.001
Gnathophis mystax (Delaroche, 1809)	3.4	0.09 ± 0.8	0.002	2.09 ± 20.15	0.002
Gobius fallax Sarato, 1889	0.3	0.01 ± 0.21	< 0.001	0.02 ± 0.32	< 0.001
Gobius geniporus Valenciennes, 1837	2	0.07 ± 0.59	0.002	0.36 ± 2.94	< 0.001
Gobius niger jozo Linnaeus, 1758	16.8	3.28 ± 13.14	0.073	64.5 ± 259.96	0.072
Gobius paganellus Linnaeus, 1758	0.3	< 0.01 ± 0.05	< 0.001	0.01 ± 0.11	< 0.001
Gonichthys coccoi (Cocco, 1829)	0.3	< 0.01 ± 0.05	< 0.001	0.01 ± 0.11	< 0.001
Helicolenus dactylopterus (Delaroche, 1809)	66.4	59.11 ± 358.36	1.317	1721.93 ± 3373.89	1.914
Heptranchias perlo (Bonnaterre, 1788)	0.6	0.01 ± 0.08	< 0.001	19.94 ± 307.9	0.022
Hoplostethus mediterraneus Cuvier, 1829	53.3	58.12 ± 209.44	1.295	1127.25 ± 3198.67	1.253
Hygophum benoiti (Cocco, 1838)	17.7	11.95 ± 88.22	0.266	7.23 ± 50.34	0.008
Hygophum hygomii (Lütken, 1892)	10.5	3.82 ± 24.25	0.085	2.47 ± 14.95	0.003
Hymenocephalus italicus Giglioli, 1884	9.1	0.85 ± 8.05	0.019	44.63 ± 572.45	0.05
Ichthyococcus ovatus Cocco, 1838	0.3	< 0.01 ± 0.05	< 0.001	0.01 ± 0.11	< 0.001
Lampanyctus crocodilus (Risso, 1810)	41.9	15.68 ± 42.67	0.349	241.6 ± 622.51	0.269

(*Continued*)

Table 3. (Continued).

	F (%)	Abundance ± SD	Abundance (%)	Biomass ± SD	Biomass (%)
Lepidopus caudatus (Euphrasen, 1788)	36.5	46.62 ± 264.94	1.038	1931.18 ± 11,940.07	2.146
Lepidorhombus boscii (Risso, 1810)	0.3	< 0.01 ± 0.05	< 0.001	0.09 ± 1.71	< 0.001
Lepidotrigla cavillone (Lacépède, 1801)	7.1	2.35 ± 14.79	0.052	51.04 ± 338.75	0.057
Lepidotrigla dieuzeidei Audouin, 1973	0.3	0.01 ± 0.11	< 0.001	0.06 ± 1.07	< 0.001
Lesueurigobius friesii (Malm, 1874)	12.8	1.76 ± 8.9	0.039	3.11 ± 15.76	0.003
Lesueurigobius sanzoi (De Buen, 1918)	11.7	4.58 ± 28.9	0.102	36.74 ± 233.4	0.041
Lesueurigobius suerii (Risso, 181)	2.6	0.91 ± 7.17	0.02	1.48 ± 11.74	0.002
Lobianchia dofleini (Zugmayer, 1911)	11.7	0.76 ± 5.11	0.017	0.58 ± 3.04	0.001
Lophius budegassa Spinola, 1807	53.6	1.57 ± 2.39	0.035	1343.72 ± 2313.21	1.493
Lophius piscatorius Linnaeus, 1758	0.9	0.01 ± 0.16	< 0.001	55.84 ± 634.5	0.062
Macroramphosus scolopax (Linnaeus, 1758)	18.5	16.01 ± 137.89	0.357	99.89 ± 949.14	0.111
Maurolicus muelleri (Gmelin, 1788)	26.8	419.01 ± 4529.53	9.334	401.83 ± 4657.77	0.447
Merluccius merluccius smiridus Rafinesque, 1810	48.7	28.86 ± 128.03	0.643	868.83 ± 1925.53	0.966
Microchirus azevia (Capello,1867)	0.6	0.02 ± 0.34	0.001	4.22 ± 59.39	0.005
Microchirus boscanion (Chabanaud,1926)	2.6	0.1 ± 0.77	0.002	1.55 ± 11.5	0.002
Microchirus ocellatus (Linnaeus, 1758)	0.9	0.02 ± 0.18	< 0.001	1.08 ± 12.18	0.001
Microchirus variegatus (Donovan, 1808)	7.7	0.95 ± 7.56	0.021	11.68 ± 71.38	0.013
Micromesistius poutassou (Risso, 1826)	45.6	456.28 ± 4548.22	10.164	6018.65 ± 46,288.82	6.689
Mola mola (Linnaeus, 1758)	1.4	0.02 ± 0.2	0.001	140.51 ± 1304.08	0.156
Molva dipterygia macrophthalma (Rafinesque, 1810)	0.3	< 0.01 ± 0.05	< 0.001	0.44 ± 8.33	< 0.001
Monochirus hispidus Rafinesque, 1814	2.3	0.17 ± 1.5	0.004	1.77 ± 16.47	0.002
Mora moro (Risso, 1810)	0.9	0.01 ± 0.13	< 0.001	0.53 ± 7.16	0.001
Mullus barbatus barbatus Linnaeus, 1758	19.1	14.11 ± 76.39	0.314	521.69 ± 2154.72	0.58
Mullus surmuletus Linnaeus, 1758	18.2	3.7 ± 19.1	0.082	426.93 ± 1934.33	0.474
Mustelus mustelus (Linnaeus, 1758)	0.6	0.01 ± 0.15	< 0.001	25.26 ± 439.02	0.028
Myctophum punctatum Rafinesque, 1810	41.6	7.56 ± 74.53	0.168	11.66 ± 113.1	0.013
Myxine glutinosa Linnaeus, 1758	0.3	< 0.01 ± 0.05	< 0.001	0.06 ± 1.12	< 0.001
Nemichthys scolopaceus Richardson, 1848	3.4	0.04 ± 0.2	0.001	1.16 ± 7.78	0.001

(*Continued*)

Table 3. (Continued).

Nettastoma melanurum Rafinesque, 1819	3.1	0.04 ± 0.22	0.001	1.42 ± 12.3	0.002
Nezumia aequalis (Günther, 1878)	43.6	89.63 ± 155.35	1.997	2263.62 ± 4044.66	2.516
Notacanthus bonapartei Risso, 1840	15.1	0.55 ± 2.44	0.012	17.11 ± 62.37	0.019
Notolepis rissoi (Bonaparte, 1840)	7.1	0.16 ± 0.98	0.003	1.07 ± 5.46	0.001
Notoscopelus elongatus (Costa, 1844)	14.8	1.07 ± 6.87	0.024	4.68 ± 21.07	0.005
Ophichthus rufus (Rafinesque, 1810)	26.2	4.3 ± 19.6	0.096	174.18 ± 785.52	0.194
Ophidion barbatum Linnaeus, 1758	4	0.27 ± 3.55	0.006	5.57 ± 76.28	0.006
Ophidion rochei Müller, 1845	1.4	0.05 ± 0.43	0.001	0.68 ± 5.94	0.001
Ophisurus serpens (Linnaeus, 1758)	3.7	0.06 ± 0.32	0.001	25.55 ± 160.57	0.028
*Oxynothus centrina (*Linnaeus, 1758)	2.8	0.06 ± 0.42	0.001	119.03 ± 830.57	0.132
Pagellus acarne (Risso, 1826)	45.6	203.91 ± 670.07	4.542	13,560.2 ± 41,245.3	15.071
Pagellus bogaraveo (Brünnich, 1768)	48.7	17.91 ± 86.95	0.399	1993.41 ± 15,376.74	2.216
Pagellus erythrinus (Linnaeus, 1758)	12.5	5.38 ± 47.96	0.12	397.03 ± 2086.79	0.441
Pagrus pagrus pagrus (Linnaeus, 1758)	16.5	0.98 ± 3.28	0.022	307.65 ± 1042.7	0.342
Paralepis speciosa Bellotti, 1878	0.6	0.01 ± 0.22	< 0.001	0.09 ± 1.19	< 0.001
Peristedion cataphractum (Linnaeus, 1758)	9.1	0.47 ± 2.49	0.01	7.31 ± 33.54	0.008
Phycis blennoides (Brünnich, 1768)	61.3	17.78 ± 32.48	0.396	1599.28 ± 2498.84	1.777
Phycis Phycis (Linnaeus, 1766)	0.3	0.01 ± 0.11	< 0.001	2.34 ± 43.77	0.003
Pomatoschistus marmoratus (Risso, 1810)	6	0.59 ± 4.04	0.013	0.85 ± 5.13	0.001
Pomatoschistus microps (Kroyer, 1838)	5.1	1.64 ± 17.1	0.037	1.61 ± 16.14	0.002
Psetta maxima maxima (Linnaeus, 1758)	0.3	0.01 ± 0.11	< 0.001	5.13 ± 96.08	0.006
Pseudaphia ferreri (O. de Buen y Fage, 1908)	0.6	0.01 ± 0.15	< 0.001	0.01 ± 0.15	< 0.001
Raja asterias Delaroche, 1809	6.3	0.2 ± 0.94	0.004	254.79 ± 1182.73	0.283
Raja circularis Couch, 1838	0.9	0.01 ± 0.13	< 0.001	38.32 ± 442.55	0.043
Raja montagui Fowler, 1910	0.6	0.02 ± 0.24	< 0.001	10.66 ± 141.3	0.012
Raja naevus Müller y Henle, 1841	2.6	0.21 ± 1.52	0.005	114.01 ± 851.18	0.127
Raja oxyrhinchus Linnaeus, 1758	0.3	< 0.01 ± 0.05	< 0.001	0.77 ± 14.41	0.001
Sardina pilchardus sardina (Walbaum, 1792)	10.3	834 ± 13,520.83	18.579	3922.15 ± 55,032.25	4.359
Sardinella aurita Valenciennes, 1847	1.4	0.08 ± 1	0.002	4.11 ± 40.31	0.005

(*Continued*)

Table 3. (Continued).

	F (%)	Abundance ± SD	Abundance (%)	Biomass ± SD	Biomass (%)
Schedophilus medusophagus Cocco, 1839	0.3	< 0.01 ± 0.05	< 0.001	0.68 ± 12.81	0.001
Schedophilus ovalis Valenciennes, 1833	0.3	< 0.01 ± 0.05	< 0.001	1.81 ± 33.89	0.002
Scomber japonicus Houttuyn, 1782	4.8	2.3 ± 28.09	0.051	126.1 ± 1399.54	0.14
Scomber scombrus Linnaeus, 1758	3.4	0.16 ± 1.14	0.003	26.26 ± 186.6	0.029
Scophthalmus rhombus (Linnaeus, 1758)	0.3	0.01 ± 0.11	< 0.001	1.87 ± 35.12	0.002
Scorpaena elongata Cadenat, 1943	5.1	0.13 ± 0.67	0.003	12.61 ± 83.8	0.014
Scorpaena loppei Cadenat, 1943	1.4	0.17 ± 1.85	0.004	2.13 ± 25.98	0.002
Scorpaena notata Rafinesque, 1810	12.3	1.26 ± 6.33	0.028	68.99 ± 414.48	0.077
Scorpaena porcus Linnaeus, 1758	4.8	0.17 ± 1.01	0.004	30.34 ± 176.4	0.034
Scorpaena scrofa Linnaeus, 1758	0.6	0.01 ± 0.15	< 0.001	4.46 ± 69.62	0.005
Scyliorhinus canicula (Linnaeus, 1758)	44.2	7.61 ± 25.62	0.169	1630.72 ± 4661.65	1.812
Serranus cabrilla (Linnaeus, 1758)	17.9	4.56 ± 20.55	0.102	223.49 ± 1111.54	0.248
Serranus hepatus (Linnaeus, 1758)	31.1	38.02 ± 115.43	0.847	527.69 ± 1866.09	0.586
Solea vulgaris (Linnaeus, 1758)	1.7	0.05 ± 0.49	0.001	34.03 ± 391.86	0.038
Sphoeroides pachygaster (Müller y Troschel, 1848)	1.7	0.04 ± 0.32	0.001	12.71 ± 146.74	0.014
Sphyraena sphyraena (Linnaeus, 1758)	0.9	0.04 ± 0.49	0.001	7.51 ± 85.83	0.008
Sphyraena viridensis Cuvier, 1829	0.3	0.08 ± 1.49	0.002	4.83 ± 90.42	0.005
Spicara maena Rafinesque, 1810	11.7	18.33 ± 115.94	0.408	568.14 ± 3019.68	0.631
Spicara smaris (Linnaeus, 1758)	6.6	17.86 ± 139.28	0.398	593.77 ± 4210.15	0.66
Spondyliosoma cantharus (Linnaeus, 1758)	3.7	0.27 ± 2.87	0.006	50.32 ± 540.9	0.056
Squalus acanthias Linnaeus, 1758	0.3	0.01 ± 0.11	< 0.001	8.55 ± 160.13	0.009
Stomias boa boa (Risso, 1810)	41.6	2.13 ± 5.89	0.048	9.94 ± 25.34	0.011
Symbolophorus veranyi (Moreau, 1888)	7.7	23.57 ± 338.68	0.525	14.13 ± 183.13	0.016
Symphodus cinereus (Bonnaterre, 1788)	0.3	0.01 ± 0.11	< 0.001	0.07 ± 1.39	< 0.001
Symphurus ligulatus (Cocco, 1844)	1.1	0.01 ± 0.11	< 0.001	0.05 ± 0.49	< 0.001
Symphurus nigrescens Rafinesque, 1810	42.7	6.03 ± 31.38	0.134	31.39 ± 202.07	0.035
Synchiropus phaeton (Günther, 1861)	2.3	0.06 ± 0.57	0.001	0.41 ± 3.95	< 0.001
Torpedo marmorata Risso, 1810	8.5	0.25 ± 0.96	0.005	113.47 ± 509.08	0.126

(*Continued*)

Table 3. (Continued).

Torpedo nobiliana Bonaparte, 1835	8	0.1 ± 0.37	0.002	136.57 ± 783.57	0.152
Trachinus draco Linnaeus, 1758	11.7	1.58 ± 6.39	0.035	251.92 ± 1085.82	0.28
Trachinus radiatus Cuvier, 1829	0.3	0.01 ± 0.11	< 0.001	3.39 ± 63.52	0.004
Trachurus mediterraneus (Steindachner, 1868)	9.7	2.97 ± 12.55	0.066	130.42 ± 559.58	0.145
Trachurus picturatus (Bowdich, 1825)	6.8	0.95 ± 9.41	0.021	19.47 ± 166.88	0.022
Trachurus trachurus (Linnaeus, 1758)	34.8	161.26 ± 1078.07	3.592	1303.46 ± 6458.84	1.449
Trachyrhynchus scabrus (Risso, 1810)	28.2	21.03 ± 64.14	0.469	4843.65 ± 14,784.39	5.383
Trachyscorpia cristulata echinata (Koehler, 1896)	3.4	0.06 ± 0.37	0.001	75.72 ± 483.19	0.084
Trigla lucerna Linnaeus, 1758	2.3	0.05 ± 0.35	0.001	21.27 ± 158.12	0.024
Trigla lyra Linnaeus, 1758	1.1	0.02 ± 0.21	0.001	1.62 ± 17.75	0.002
Trigloporus lastoviza (Brünnich, 1768)	7.7	0.87 ± 5.03	0.019	31.62 ± 161.23	0.035
Trisopterus minutus capelanus (Lacépède, 1800)	0.3	0.07 ± 1.28	0.002	0.22 ± 4.06	< 0.001
Uranoscopus scaber Linnaeus, 1758	6.6	0.21 ± 0.9	0.005	76.59 ± 340.03	0.085
Vinciguerria attenuata (Cocco, 1838)	0.9	0.01 ± 0.09	< 0.001	0.01 ± 0.13	< 0.001
Vinciguerria poweriae (Cocco, 1838)	0.9	0.01 ± 0.09	< 0.001	0.01 ± 0.09	< 0.001
Zenopsis conchifer (Lowe, 1852)	0.3	0.01 ± 0.11	< 0.001	0.22 ± 4.06	< 0.001
Zeus faber Linnaeus, 1758	4.8	0.21 ± 1.29	0.005	70.84 ± 558.18	0.079

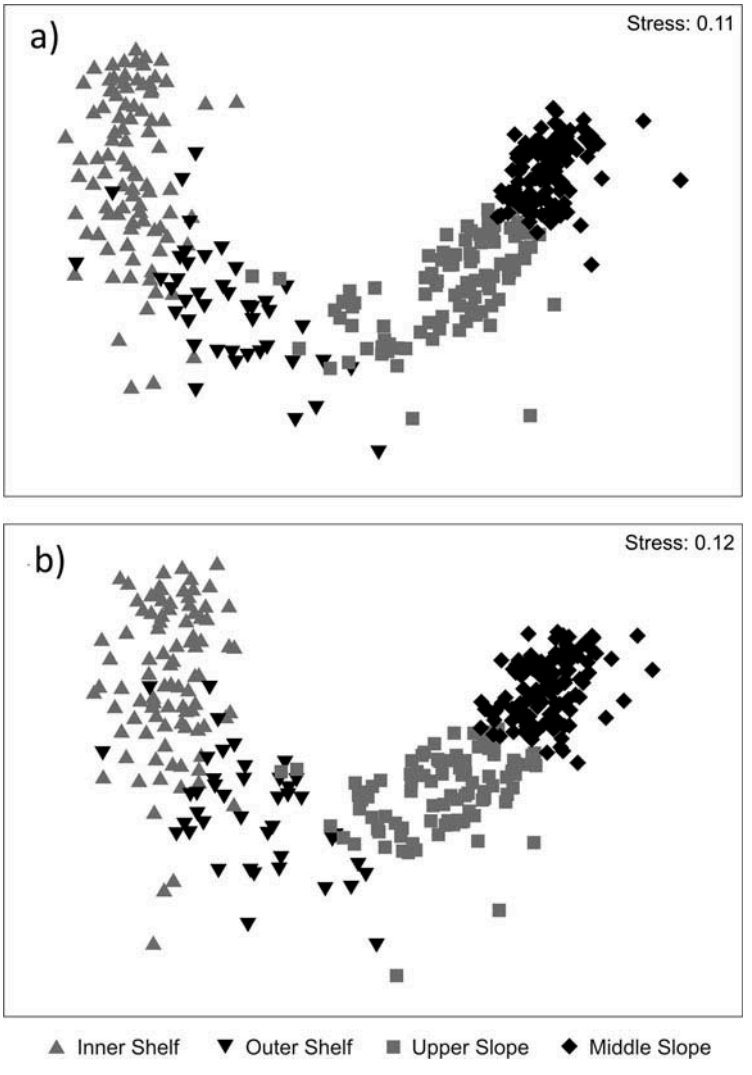


Figure 2. Non-metric multidimensional scaling (nMDS) analyses using (a) abundance and (b) biomass of fish species collected in the different hauls.

Abundance, biomass, mean fish weight and species richness of fish assemblages

Mean values of abundance, biomass and mean fish weight per hour of the assemblages obtained in the multivariate analysis of assemblages are given in Figure 3.

Mean abundance differed significantly between assemblages (Kruskal–Wallis, Table 6), sharply decreasing in the US assemblage in comparison to IS and OS assemblages, and showing minimum values in the MS.

Mean biomass was also significantly different between assemblages (Kruskal–Wallis, Table 6), with maximum values in IS, followed by MS and OS, and minimum values in US.

Table 4. Permutational multivariate analysis of variance (PERMANOVA) based on resemblance matrix of (a) abundance data and (b) biomass data from hauls performed on MEDITS survey (9999 permutations) in response to groups identified by non-metric multidimensional scaling (nMDS) analysis (factor level was 4).

Source	df	MS	Pseudo-F	p
(a)				
Groups	3	25.782	234.36	< 0.01
Residual	347	0.110		
Total	350			
(b)				
Groups	3	22.694	205.61	< 0.01
Residual	347	0.110		
Total	350			

Mean fish weight was the highest in the MS assemblage, with significant differences between assemblages (Kruskal–Wallis, Table 6). Table 7 shows species whose mean fish weight was positively and significantly correlated with depth (Spearman correlation value > 0.5).

There were differences among the species rarefaction curves for each assemblage constructed for a common number of hauls (n = 40) and decreasing numbers of species with increasing depth (Figure 4). The highest values were found over the continental shelf, followed by those of the upper and middle slopes, respectively.

Longitudinal variability within the Alboran Sea

nMDS analysis performed with abundance data showed some degree of separation between hauls depending on their location (Figure 5). This separation was evident within the IS and OS assemblages (Figure 5a and 5b, respectively). From 200 to 800 m, the nMDS analyses did not show great geographical affinities between samples within US and MS assemblages (Figure 5c and 5d, respectively).

Within the IS assemblage, differences were mainly evident between Punta Entinas and Cabo de Gata, and the other sampled areas (Figure 5a). These differences were due to several species that showed significant differences in their abundance values (Kruskal–Wallis, $p < 0.01$) between locations (Table 8). We distinguished two groups of species in relation to their abundance data in the study area: (1) species almost absent in Punta Entinas and Cabo de Gata (*C. aper, Callionymus maculatus, Cepola rubescens, Gobius niger jozo, Lesueurigobius sanzoi, Macroramphosus scolopax, Microchirus variegatus* and *Symphurus nigrescens*) and (2) species very abundant in Punta Entinas and Cabo de Gata but totally absent (*Spicara smaris*) or very scarce (*Spicara maena*) in the rest of the study area.

No clear longitudinal trends were evident for *C. aper*, *C. maculatus*, *L. sanzoi*, *M. scolopax* and *S. nigrescens* within the OS assemblage. Nevertheless, *C. rubescens* still displayed significant differences between locations, as observed in the IS assemblage (Table 9). *Gobius niger jozo* and *M. variegatus* were almost absent below 100 m, and *S. maena* and *S. smaris* were never caught at that depth. nMDS analysis of the OS assemblage identified Almeria and Roquetas as the closest samples (Figure 5b). The

Table 5. Percentage of similarity routine (SIMPER) analyses (a) average similarity and (b) average dissimilarity of comparisons between groups of non-metric multidimensional scaling (nMDS) analysis. The cut-off point of the cumulative contribution is set to 90%. Abundance data (ind h^{-1}).

(a) Species	Av.Abund	Av.Sim	Contrib%	Cum.%
Group inner continental shelf (30–100 m): average similarity = 15.31				
Pagellus acarne	724.28	5.11	33.35	33.35
Serranus hepatus	116.81	2.34	15.26	48.62
Boops boops	258.45	1.74	11.39	60
Capros aper	2071.15	1.28	8.37	68.38
Trachurus trachurus	596.91	1.22	7.95	76.33
Cepola rubescens	56.43	0.58	3.8	80.13
Merluccius merluccius smiridus	34.96	0.58	3.8	83.93
Mullus barbatus barbatus	51.62	0.34	2.21	86.13
Arnoglossus thori	32.91	0.28	1.8	87.94
Spicara maena	68.43	0.25	1.66	89.6
Callionymus maculatus	28.57	0.19	1.27	90.87
Group outer continental shelf (100–200 m): average similarity = 15.26				
Capros aper	4724.67	9.16	60.07	60.07
Gadiculus argenteus argenteus	597.38	1.66	10.87	70.94
Maurolicus muelleri	2932.1	0.89	5.84	76.78
Pagellus acarne	79.62	0.55	3.63	80.41
Micromesistius poutassou	2627.81	0.5	3.28	83.69
Merluccius merluccius smiridus	144.62	0.47	3.11	86.8
Helicolenus dactylopterus	216.1	0.45	2.95	89.75
Scyliorhinus canicula	33.81	0.3	1.94	91.7
Group upper slope (200–500 m): average similarity = 21.73				
Coelorhynchus coelorhynchus	179.86	6.66	30.65	30.65
Hoplostethus mediterraneus	145.14	3.52	16.18	46.83
Phycis blennoides	39.82	1.9	8.76	55.59

(*Continued*)

Table 5. (Continued).

Gadiculus argenteus argenteus	222.81	1.85	8.51	64.1
Micromesistius poutassou	257.97	1.47	6.77	70.87
Epigonus denticulatus	28.35	1.23	5.66	76.53
Galeus melastomus	68.93	0.83	3.8	80.33
Helicolenus dactylopterus	98.45	0.65	2.98	83.31
Lepidopus caudatus	41.92	0.61	2.82	86.13
Nezumia aequalis	21.79	0.25	1.16	87.29
Maurolicus muelleri	56.97	0.25	1.15	88.43
Myctophum punctatum	21.64	0.23	1.08	89.51
Conger conger	5.44	0.22	1	90.51
Group middle slope (500–800 m): average similarity = 47.21				
Galeus melastomus	259.02	16.87	35.73	35.73
Nezumia aequalis	244.92	16.71	35.4	71.12
Hoplostethus mediterraneus	55.11	3.78	8.02	79.14
Trachyrhynchus scabrus	61.47	1.87	3.97	83.11
Lampanyctus crocodilus	39.53	1.85	3.92	87.03
Etmopterus spinax	27.45	1.68	3.55	90.58

(b) Species	Group IS Av.Abund	Group OS Av.Abund	Av.Diss	Contrib%	Cum.%
Groups innser shelf (30–100 m) and Outer shelf (100–200 m) = average dissimilarity = 92.28					
Capros aper	2071.15	4724.67	27.41	29.7	29.7
Maurolicus muelleri	196.68	2932.1	9.59	10.39	40.1
Pagellus acarne	724.28	79.62	8.29	8.98	49.08
Micromesistius poutassou	265.45	2627.81	7.89	8.55	57.63
Gadiculus argenteus argenteus	0.11	597.38	6.72	7.29	64.92
Trachurus trachurus	596.91	9.67	4.07	4.41	69.34
Boops boops	258.45	16.62	3.09	3.35	72.69

(*Continued*)

Table 5. (Continued).

(b) Species	Group IS Av.Abund	Group OS Av.Abund	Av.Diss	Contrib%	Cum.%
Sardina pilchardus sardina	3114.19	0	2.51	2.72	75.41
Lepidopus caudatus	10.96	266.67	2.38	2.58	78
Merluccius merluccius smiridus	34.96	144.62	2.16	2.35	80.34
Serranus hepatus	116.81	56.24	1.9	2.06	82.4
Helicolenus dactylopterus	0.6	216.1	1.44	1.56	83.96
Pagellus bogaraveo	40.94	26.1	1.34	1.45	85.41
Engraulis encrasicolus	737.21	0	1.03	1.11	86.52
Cepola rubescens	56.43	11.14	1	1.09	87.61
Scyliorhinus canicula	3.45	33.81	0.9	0.98	88.59
Macroramphosus scolopax	25.15	77.1	0.87	0.94	89.53
Spicara maena	68.43	0	0.87	0.94	90.47
Groups outer shelf (100–200 m) and upper slope (200–500 m): average dissimilarity = 95.45					
Capros aper	4724.67	33.45	28.81	30.18	30.18
Micromesistius poutassou	2627.81	257.97	10.63	11.14	41.32
Maurolicus muelleri	2932.1	56.97	10.26	10.75	52.07
Gadiculus argenteus argenteus	597.38	222.81	10.15	10.63	62.7
Coelorhynchus coelorhynchus	0.19	179.86	4.01	4.2	66.9
Lepidopus caudatus	266.67	41.92	3.52	3.69	70.59
Hoplostethus mediterraneus	0	145.14	2.98	3.12	73.71
Helicolenus dactylopterus	216.1	98.45	2.88	3.01	76.72
Merluccius merluccius smiridus	144.62	7.96	2.54	2.66	79.38
Pagellus acarne	79.62	1.31	2.38	2.5	81.88
Galeus melastomus	0	68.93	1.45	1.52	83.4
Scyliorhinus canicula	33.81	9.35	1.25	1.31	84.71
Pagellus bogaraveo	26.1	7.62	1.18	1.24	85.95
Phycis blennoides	2.9	39.82	1.08	1.13	87.07

(*Continued*)

Table 5. (Continued).

Macroramphosus scolopax	77.1	0.19	0.98	1.03	88.1
Symbolophorus veranyi	0.67	80.74	0.82	0.86	88.95
Hygophum benoiti	0	39.49	0.8	0.84	89.79
Benthosema glaciale	140	14.67	0.79	0.83	90.62
Groups upper slope (200–500 m) and middle slope m (500–800 m): average dissimilarity = 85.04					
Galeus melastomus	68.93	259.02	13.17	15.49	15.49
Nezumia aequalis	21.79	244.92	12.31	14.47	29.96
Coelorhynchus coelorhynchus	179.86	19.69	8.09	9.51	39.48
Gadiculus argenteus argenteus	222.81	0.06	6.51	7.65	47.13
Hoplostethus mediterraneus	145.14	55.11	6.05	7.11	54.24
Micromesistius poutassou	257.97	2.73	5.42	6.37	60.61
Helicolenus dactylopterus	98.45	18.87	3.34	3.92	64.54
Trachyrhynchus scabrus	0.07	61.47	3.03	3.57	68.11
Lampanyctus crocodilus	7.98	39.53	2.25	2.65	70.76
Phycis blennoides	39.82	19.47	2.15	2.53	73.29
Maurolicus muelleri	56.97	0.22	2.04	2.4	75.68
Lepidopus caudatus	41.92	1.26	2.02	2.38	78.06
Hygophum benoiti	39.49	3.68	1.83	2.16	80.22
Symbolophorus veranyi	80.74	4.78	1.78	2.09	82.31
Etmopterus spinax	11.39	27.45	1.76	2.07	84.39
Epigonus denticulatus	28.35	2.75	1.61	1.9	86.28
Ceratoscopelus maderensis	30.31	1.46	1.32	1.56	87.84
Alepocephalus rostratus	0	24.23	1.15	1.35	89.19
Benthosema glaciale	14.67	2.77	1	1.18	90.37

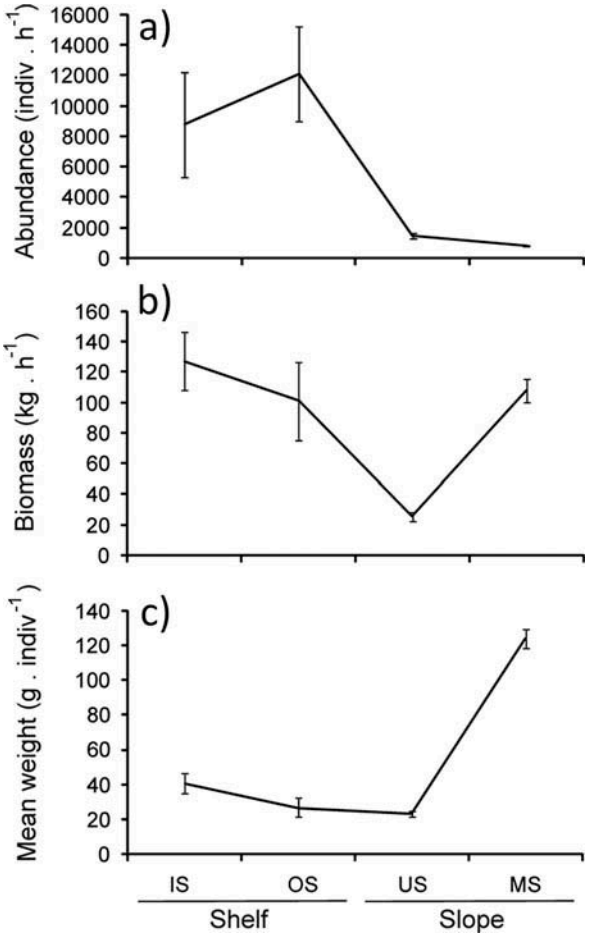


Figure 3. Mean values of (a) abundance (ind h^{-1}), (b) biomass (kg h^{-1}) and (c) species mean weight (g ind^{-1}) in the different assemblages characterised. IS: Inner continental shelf (30–100 m); OS: outer continental shelf (100–200 m); US: upper continental slope (200–500 m); MS: middle continental slope (500–800 m). Bars represent ± standard error (SE).

differences between these locations and the others were influenced by the significant differences in abundance of the species listed in Table 9. In both locations, *S. hepatus* and *Merluccius merluccius smiridus* displayed the highest abundance values. As indicated above, *C. rubescens* was only captured in Almeria, Roquetas and Fuengirola at this depth. The species *Maurolicus muelleri* was very abundant in Malaga and Fuengirola.

Discussion

Ichthyofaunal composition

The 186 species identified in the present study account for 27% of the total number of fish species in the Mediterranean Sea (684). Of the four ichthyofaunal Mediterranean

Table 6. Significance tests (Kruskal–Wallis) between assemblages identified for mean values of fish abundance, biomass and species mean weight. (IS: Inner continental shelf, 30–100 m; OS: outer continental shelf, 100–200 m; US: upper continental slope, 200–500 m; MS: middle continental slope, 500–800 m).

	df	Statistic	*p*-values	Groups
Abundance	3	H = 72.5	$p < 0.01$	IS < OS > US = MS
Biomass	3	H = 95.3	$p < 0.01$	IS = OS > US < MS
Mean weight	3	H = 190.5	$p < 0.01$	IS > OS > US < MS

Table 7. Spearman correlation coefficient between species mean weight and depth, calculated for fish species captured during 1994–2005 MEDITS survey series, and whose correlation values were higher than 0.5.

	Spearman coefficient
Alepocephalus rostratus	0.56
Argyropelecus hemigymnus	0.60
Chimaera monstrosa	0.76
Etmopterus spinax	0.85
Galeus melastomus	0.90
Helicolenus dactylopterus	0.71
Hoplostethus mediterraneus	0.88
Lampanyctus crocodilus	0.82
Nezumia aequalis	0.87
Phycis blennoides	0.92
Stomias boa	0.63
Trachyrhynchus scabrus	0.74

classes, three are recorded (Myxini, Chondrichthyes and Osteichthyes). Twenty four (72.7%) of the 33 Mediterranean orders (Lloris 2008) have been recorded in this study of fish assemblages in the northern Alboran Sea.

Of the 186 species caught, 46 are occasional species, since they only appear in one or two samples throughout the 12-year series. The low frequency of occurrence of these species may be due to different causes: (1) the type of sampling carried out (depth intervals and types of ground sampled), (2) the characteristics and geometry of fishing gear and (3) the particular behaviour and life cycle of these species (Lloris et al. 2000). As for fishing gear, in a study off the Catalan coast, Cartes et al. (2009) showed the influence of trawl type on the composition and diversity of deep benthopelagic fish and decapod assemblages.

In terms of biogeographical distribution, in this work, the number of species and subspecies with typical Atlantic distribution is high: 75% (140 species). These include 74 Atlantic-African species, followed by 44 Atlantic-European and 22 Amphi-Atlantic. Of the remainder, 19 are endemic Mediterranean, 14 cosmopolitan and 13 circumglobal. No species with Indo-Pacific or Lessepsian distribution have been registered. Endemic Mediterranean components appear more clearly at the species

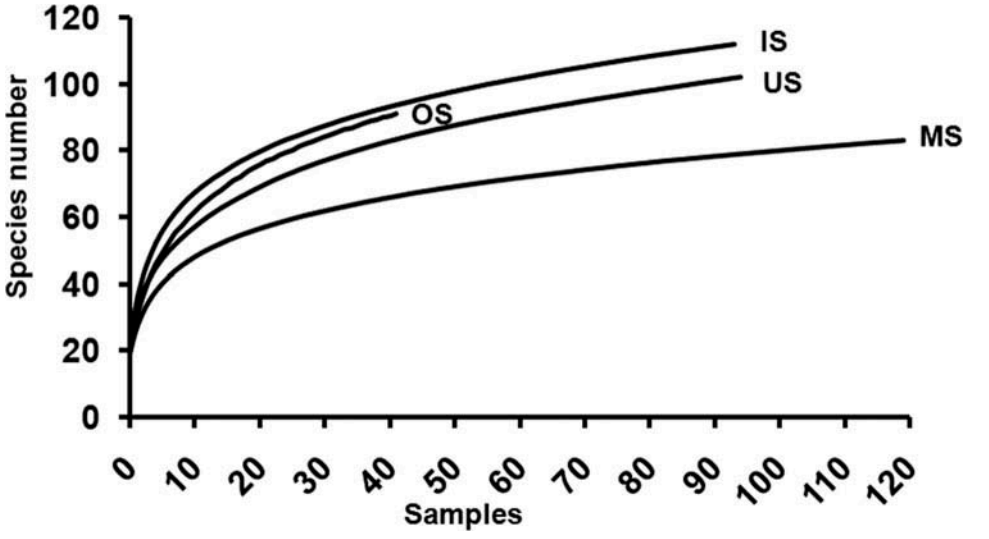
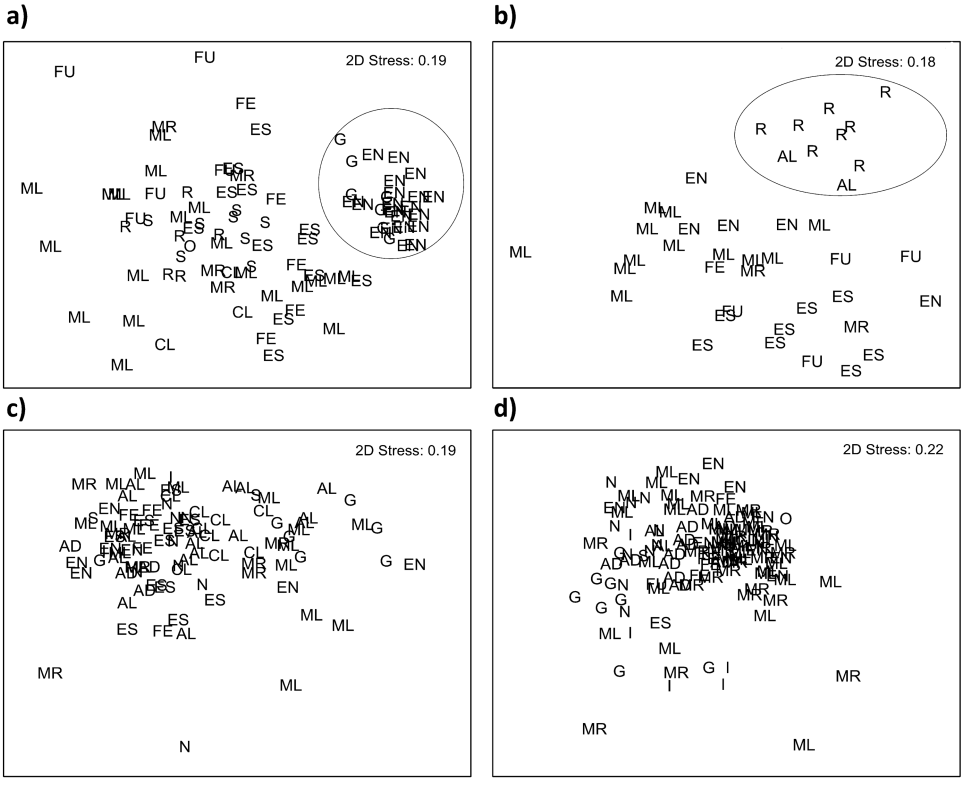


Figure 4. Species rarefaction curves for the fish assemblages within the inner continental shelf (IS, 30–100 m), outer continental shelf (OS, 100–200 m), upper continental slope (US, 200–500 m) and middle continental slope (MS, 500–800 m). The *x*-axis represents the number of samples for each group.

rather than the genus level and are considered to be 'neo-endemisms', a fact that, together with their great affinity with Atlantic fauna, reflects their recent nature (Fredj et al. 1992). Of the 19 endemic species and subspecies, 13 are exclusive to the continental shelf and the rest are from the slope. The reduction in the number of endemisms according to depth was observed by Stefanescu (1991), who stated that, for the entire Mediterranean Sea, deep ichthyofauna (e.g. Catalan Sea) at depths greater than 1000 m is characterised by very few endemic species. Within the endemic species, the Gobiidae family is the best represented in the Alboran Sea, with six species and subspecies. Quignard and Tomasini (2000) suggested that 46% of Mediterranean endemic species belong to this family, probably due to the fact that Gobiidae displays the highest number of species in the Mediterranean in comparison with other families.

Two species recorded in this study have not been reported in the Mediterranean Sea beyond Cabo de Gata: *Galeus atlanticus* (Elasmobranchii) and *L. sanzoi* (Osteichthyes). The distribution of *G. atlanticus* extends westward from the Strait of Gibraltar to the Atlantic coast of the Southern Iberian Peninsula and Southern Portugal (Rey et al. 2010); in fact, in Spanish waters of the Gulf of Cadiz, *G. atlanticus* is a dominant species, in terms of biomass, in several places sampled between 500 and 600 m depth (Delgado et al. 2013). Its western distribution boundary is off Cabo St. Vicent (southwestern limit of Portugal). There are records of a specimen preserved from Cabo Espartel and from those of Muñoz-Chápuli and Ortega (1985) collected from the Moroccan Mediterranean Coast. Eastwards, the distribution boundary of *G. atlanticus* is Cabo de Gata. The absence of the species in the rest of the Mediterranean Sea could be due to the different oceanographic conditions (Rey et al. 2010). Throughout the Alboran Sea the species shows a



From west to east: Estepona (ES), Marbella (MR), Fuengirola (FU), Malaga (ML), Caleta de Velez (CL), Nerja (N), Salobreña (S), Castell de Ferro (FE), Alboran Island (I), Adra (AD), Seco de los Olivos (O), Sabinal-Punta Entinas (EN), Roquetas (R), Almeria (AL), Cabo de Gata (G).

Figure 5. Non-metric multidimensional scaling (nMDS) analyses using fish abundance data (ind h^{-1}). One- or two-letter labels stand for the sampled location. (a) Inner continental shelf (30–100 m); (b) outer continental shelf (100–200 m); (c) upper continental slope (200–500 m); (d) middle continental slope (500–800 m).

heterogeneous distribution: it is fairly common in the central part of the basin in waters off Malaga and Nerja, and off Alboran Island (east and west), is less common in the western and easternmost areas of the Alboran Sea and is absent in Cabo de Gata waters.

L. sanzoi is considered an Atlantic species of recent inclusion in the Mediterranean Sea (Fredj and Maurin 1987; Quignard and Tomasini 2000). The distribution is eastern Atlantic (Morocco and Canaries) and western Mediterranean Sea (Alboran Sea) (Whitehead et al. 1984–1986). High captures of *L. sanzoi* were recorded at Gulf of Cadiz stations sampled in April 1996 (Sobrino et al. 1996). Its absence throughout the rest of the Mediterranean Sea could concur with the heterogeneous geographic distribution of this species throughout the northern Alboran Sea between 30 and 100 m depth, and its recorded absence at Punta Entinas and Cabo de Gata.

Table 8. Comparison of mean abundance values (N, ind h^{-1}) and frequency of occurrence (F, %) showing significant differences (Kruskal–Wallis, $p < 0.01$) between localities for species within the bathymetric assemblage of the inner continental shelf (IS, 30–100 m). The number of samples for each location is given in parentheses.

		Inner continental shelf (30–100 m)										
		ES (12)	MR (4)	FU (5)	ML (21)	CL (3)	S(8)	FE (5)	O (1)	EN (22)	R (6)	G (7)
C. aper	**N**	8624	3010	10,931	945	161	131	48	40	1	469	1
	F	8	4	5	15	2	7	2	1	3	6	3
C. maculatus	**N**	22	72	117	38	9	46	1	166	0	30	1
	F	9	4	5	12	3	7	2	1	2	6	2
C. rubescens	**N**	0	7	94	87	193	150	65	160	0	119	1
	F	1	4	4	16	3	8	5	1	0	6	2
G. niger jozo	**N**	7	17	8	21	15	33	3	30	0	16	0
	F	8	2	2	16	3	8	4	1	1	6	1
L. sanzoi	**N**	27	0	1	34	35	22	3	8	0	20	0
	F	3	0	1	15	3	5	1	1	1	6	0
M. scolopax	**N**	3	43	400	4	1	1	1	0	0	10	0
	F	3	3	4	7	1	2	1	0	1	4	0
M. variegatus	**N**	10	3	1	6	0	3	1	0	0	0	1
	F	8	2	1	1	0	2	1	0	4	0	4
S. maena	**N**	0	0	0	3	1	0	6	0	267	16	52
	F	2	0	0	4	1	0	3	0	21	3	6
S. smaris	**N**	0	0	0	0	0	0	0	0	189	0	300
	F	0	0	0	0	0	0	1	0	15	0	7
S. nigrescens	**N**	4	49	6	35	2	18	1	0	0	8	0
	F	7	3	2	9	2	6	2	0	0	3	1

Note: ES, Estepona; MR, Marbella; FU, Fuengirola; ML, Málaga; CL, Caleta de Vélez; S, Salboreña; FE, Castell de Ferro; O, Seco de los Olivos; EN, P. Entinas; R, Roquetas; G, Cago de Gata.

Table 9. Comparison of mean abundance values (N, ind h^{-1}) and frequency of occurrence (F, %) showing significant differences (Kruskal–Wallis, $p < 0.01$) between localities for species within the bathymetric assemblage of the Outer continental shelf (OS, 100–200 m). The number of samples for each location is given in parentheses.

		Outer continental shelf (100–200 m)							
		ES (8)	MR (2)	FU (4)	ML (12)	FE (1)	EN (5)	R (8)	AL (2)
C. rubescens	**N**	0	0	6	0	0	0	55	9
	F	0	0	1	0	0	0	8	2
M. merluccius	**N**	3	4	10	18	8	517	351	204
	F	6	1	1	8	1	5	8	2
M. muelleri	**N**	39	680	19,779	3478	386	7	25	0
	F	4	1	2	12	1	2	2	0
S. hepatus	**N**	0	0	30	1	0	7	247	155
	F	0	0	1	2	0	1	8	2

Note: ES, Estepona; MR, Marbella; FU, Fuengirola; ML, Málaga; FE, Castell de Ferro; EN, P. Entinas; R, Roquetas; AL, Almeria.

Identified assemblages

We have identified four main assemblages in the northern Alboran Sea corresponding to the following bathymetric ranges: inner shelf (30–100 m), outer shelf (100–200 m), upper slope (200–500 m) and middle slope (500–800 m). Their limits are not strict and often overlap, probably influenced by differences between geographic locations. Despite continuous faunal renewal along the bathymetric gradient, many marine environmental studies have established zonation models with boundaries along this gradient and resulting in different groups of species (Haedrich and Merrett 1990; Hecker 1990; Stefanescu et al. 1993, 1994; Moranta et al. 1998; D'Onghia et al. 2004). However, groups do not usually overlap within a given locality (Hecker 1990).

Successive assemblages from the northern Alboran Sea displayed the strongest differences between the outer shelf and the upper slope. The differences concern not only abundance and biomass, but also the presence/absence of certain species. Hecker (1990) proposed a zonation model related to physical and biological factors, such as seabed physiography and geology, and the availability of trophic resources, and suggested a continuous faunal renewal along the bathymetric gradient, where large depth bands with a very low rate of faunal changes alternate with others where the replacement of some species is more acute. According to this author, changes in faunistic composition between groups are due to dominant species replacement throughout the depth gradient. Thus, the inner shelf assemblage (30–100 m) of the Alboran Sea is characterised by a high abundance of species, including *P. acarne*, *S. hepatus* and *B. boops*. Higher catches of smaller species (*C. aper*, *G. argenteus* and *M. muelleri*) were generally made on the outer shelf (100–200 m), which has the highest abundance values. This depth range is coincident with the edge of the continental shelf. A study on the physiographic characterisation of Alboran Sea margins showed that the mean slope of the seabed in the inner shelf (down to 100 m) was 0.5° (Bárcenas 2002). From this depth to approximately 150 m further down, the shelf edge is located and characterised by a sharp rise in the slope of up to 4° (Vázquez 2005), which defines the boundary between the continental shelf and the beginning of the continental slope. The continental shelf edge is generally an area of high energy resulting from turbulence caused by fronts separating water masses from the shelf and the continental slope, which causes an increase in phytoplankton and zooplankton biomass and results in an important feeding area for large fish (Colloca et al. 2004). The upper slope (200–500 m) is characterised by a sharp decline in both the abundance and biomass of species. The dominant species are *C. coelorhynchus*, *H. mediterraneus* and *P. blennoides*. The lowest mean species weight is recorded on the upper slope and the outer shelf. The middle slope showed a sharp increase in biomass compared with the upper slope due to the greater mean weight of some species of this bathymetric group. This increase is related to the larger size of the most abundant species from this depth range in comparison with that of other bathymetric assemblages (IS, OS, MS). In the middle slope assemblage, certain species (e.g., *G. melastomus*) tended to increase in size with depth. *Galeus melastomus* and *N. aequalis* are the most abundant species in the middle slope. Our study highlights the high ichthyofaunal similarity between samples from the middle slope, compared with those from the other assemblages.

Several studies on the distribution of fish species throughout the Mediterranean reveal the existence of zonation patterns (Stefanescu et al. 1994; D'Onghia et al. 1998;

Moranta et al. 1998; Kallioniotis et al. 2000; Labropoulou and Papaconstantinou 2000). All of them show the existence of different assemblages that also differ in their faunistic composition. However, our study reveals that there are some differences between the Alboran Sea and other Mediterranean areas. In the Alboran Sea, fish biomass increased significantly from 500 m, whereas this increase occurs between 800 and 1400 m depth in the Catalan Sea (Stefanescu et al. 1994), or between 800 and 1200 m on the continental slope of the Balearic Islands (Algerian sub-basin; Moranta et al. 1998), with a further decrease below those depths.

The increase in biomass from 500 m depth in the Alboran Sea is related to the dominance of *G. melastomus*, *N. aequalis*, *T. scabrus* and *C. monstrosa*, much more abundant in the Alboran Sea than in other Mediterranean areas. The differences in the abundance of *G. melastomus* observed between the Alboran Sea and elsewhere in the Mediterranean have been highlighted by several authors, who conclude that these differences are caused by the fishing effort which is lower in the Alboran Sea below a depth of 500 m (Tursi et al. 1993; Massutí and Moranta 2003; Rey et al. 2005). On the other hand, *C. monstrosa* – the second chondrichthyan species in terms of biomass – is relatively common in the Alboran Sea, whereas this species is scarce or absent in the northern area of the Balearic Islands (Massutí and Moranta 2003), despite a wide bathymetric sampling coverage (up to 1800 m) and the fact that *C. monstrosa* lives in waters up to 1300 m (Lloris 2008). Gouraguine et al. (2011) also recorded few small-sized specimens in comparison to those from the Alboran Sea in their study around the continental shelf and the upper slope of Majorca and Minorca (Balearic Islands). Stefanescu (1991) reported the occasional presence of *C. monstrosa* in the Catalan Sea (two individuals in 48 samples). Abundance differences for *N. aequalis* and *T. scabrus* have also been found along the Iberian Mediterranean coast (Moranta et al. 2007). The authors reveal the decreasing south-to-north trend of these species and pinpoint the particular oceanographic conditions of the Alboran Sea as a possible cause, before finally concluding that the impact of fishing exploitation could mask the effect of abiotic factors. Such abiotic factors may be related to the physiography of the continental slope. Major faunal changes coincide with changes in the relative inclination of the slope and the availability of food resources (Hecker 1990). In a study from 1952, Cartes et al. (2013) suggest that small changes in the hydrological conditions (Temperature, Salinity and dissolved O_2) of deep-water masses in the generally stable environmental deep Balearic Basin can contribute to some significant changes in fish and crustaceans.

Surveys carried out in the Gulf of Cadiz (Sobrino et al. 1996; Delgado et al. 2013) and along the northern Iberian slope (Serrano et al. 2011) have shown that *G. melastomus*, *N. aequalis*, and *C. monstrosa* are very abundant species. Within the Alboran Sea, these species are distributed differently at Cabo de Gata and in the eastern part of Alboran Island, where *G. melastomus* and *N. aequalis* are less abundant. *Chimaera monstrosa* is not captured at Cabo de Gata or Alboran Island, and *T. scabrus* is not present at Cabo de Gata, with only a few specimens caught at Alboran Island (García-Ruiz 2012). According to these results and concerning the distribution of these four species, it appears that the Alboran Sea (excepting Cabo de Gata and to the east of Alboran Island) shares more similarities with the adjacent Atlantic Ocean than with the rest of the Mediterranean.

The decreasing number of species with increasing depth recorded in this study concurs with previous findings in different areas of the Mediterranean (Pérès 1985;

Stefanescu 1991; Moranta et al. 1998; Kallianiotis et al. 2000; Quignard and Tomasini 2000; Labropoulou and Papaconstantinou 2000; Emig and Geistdoerfer 2004) and Atlantic (Fariña et al. 1997; Moranta et al. 1998; Sánchez et al. 2002). For depths greater than those considered in this study, Moranta et al. -(1998) indicated a progressive impoverishment along the bathymetric gradient down to 1800 m in the Balearic Islands (Algerian basin, Western Mediterranean). Furthermore, Stefanescu (1991) and Stefanescu et al. (1993) also identified lower species richness in the Catalan Sea between 1000 and 2250 m depth, although it was more acute in the lower (1425–2250 m) than in the middle (1000–1425 m) slope. This decline is probably related to the disappearance at around 1000–1200 m of mesopelagic fauna that plays a key role in the feeding ecology of demersal species.

Longitudinal distribution

As for geographical distribution, spatial differences between a few species' distributions seem to occur within the continental shelf assemblages (inner and outer shelf).

Within the inner shelf, the abundances of some species were significantly different, in locations such as Punta Entinas and Cabo de Gata, to other locations in the same depth range. *Capros aper* is one of the species that shows major differences in abundance between localities at depths up to 100 m. It is a very abundant species in the inner continental shelf (30–100 m), with very high catches during the early years of the studied series (García-Ruiz 2012) and present at all the sampled locations of this bathymetric stratum, except Punta Entinas and Cabo de Gata – where this species is absent. Studies in the Northeast Atlantic suggest that there is a high correlation with physical and biological factors, in a given year, in the reproductive strategy of *C. aper* (Farrell et al. 2012). In that area, recorded increases in abundance during certain periods have been attributed to variations in the temperature of the water column (Blanchard and Vandermeirsch 2005). *Macroramphosus scolopax* is another species which, like *C. aper*, has also not been captured in any of the Punta Entinas or Cabo de Gata samples taken between 30 and 100 m depth. However, our work shows that both species appear throughout the study area between 100 and 200 m depth. In the northern Alboran Sea, factors affecting the distribution of *C. aper* and *M. scolopax* seem to change at this depth, allowing these species to proliferate at all the locations sampled.

Other less abundant species share similar spatial distribution at depths up to 100 m: *C. maculatus*, *G. niger jozo*, *L. sanzoi*, *S. nigrescens* and *M. variegatus.*

By contrast, two other species (*S. smaris* and *S. maena*) have contrasting geographical distributions in the study area: abundant at Punta Entinas and Cabo de Gata but totally absent (*S. smaris*) or very scarce (*S. maena*) in the remaining locations. Both species are also abundant elsewhere in the waters of the Iberian Mediterranean Sea (Garcia-Rodríguez et al. 2011), but scarce (*S. maena*) or completely absent (*S. smaris*) in a survey carried out in the Gulf of Cadiz in April 1996 (Sobrino et al. 1996). This same survey recorded abundant catches of *L. sanzoi* at that depth range – *L. sanzoi* is absent in the rest of the Mediterranean Sea, as previously mentioned. Up to 100 m, with the exception of Punta Entinas and Cabo de Gata, the Alboran Sea is more similar to the Atlantic than to the rest of the Mediterranean in terms of the distribution of some species. Punta Entinas and Cabo de Gata, on the other hand, appear to be more similar to the rest of the Iberian Mediterranean Sea.

From the data available we presume that Punta Entinas and Cabo de Gata areas could have different characteristics than the rest of the study area because of the distribution of some species in both locations. These species could be used as indicators of different environmental scenarios. Available data were not sufficient to explain the differences. Nevertheless, on the basis of the data from RADMED (Radiales del Mediterráneo) cruises (C. García-Martínez, pers. comm.) some variables such as temperature, salinity, chlorophyll a, nutrient concentration and microphytoplankton abundances from Cabo de Gata have been compared with other locations of the study area (Cabo Sacratif; Figure 1). The data were collected during the 2008, 2009, 2010 and 2011 spring RADMED cruises. Below 40 m, the values of salinity are higher at Cabo de Gata than Cabo Sacratif. Surprisingly, a clear subsurface maximum in the mean microphytoplankton abundance appears at Cabo Sacratif (at around 10 m), while this expected maximum does not appear at Cabo de Gata. However, the Cabo de Gata profile of mean nutrient concentration showed much lower values than at Cabo Sacratif. This could be the underlying reason for the lower phytoplankton abundances at Cabo de Gata since they sustain lower zooplankton concentrations. Despite the temporal mismatch between these data and our analysis, differences in Cabo de Gata and Cabo Sacratif are highlighted. Further investigations should be carried out to analyse species and environmental data relationships in order to better understand the dynamics of fish distribution.

This work has also identified differences within the outer shelf assemblage (between 100 and 200 m). *Merluccius merluccius* is heterogeneously distributed throughout the study area and is very abundant in Almeria, Roquetas and Punta Entinas, but declines sharply from there to Estepona. We note that the geographical differences only occur in that depth range, without major changes in the other bathymetric ranges. We have captured this species from 40 to 714 m, but its abundance drops considerably below 300 m. The highest abundances are found between 100 and 200 m depth, which concurs with higher catches of *M. merluccius* at this depth interval (100–200 m) in other Mediterranean areas reported by Orsi Relini et al. (2002) in their work on the distribution of this species – based on MEDITS surveys conducted between 1994 and 1999. The authors located most of the *M. merluccius* breeding areas at this depth interval.

The species *M. muelleri* is also heterogeneously distributed in the Alboran Sea. In our study, its distribution range is between 50 and 700 m depth, but the species is most abundant from 100 to 200 m, with massive catches in Malaga, Marbella and Fuengirola. At other places or other depth intervals, *M. muelleri* is captured in small amounts or not at all. According to Pérez de Rubin (1996), *M. muelleri* is abundant in the western Mediterranean, especially in the Alboran Sea where the highest numbers of eggs and larvae are found in divergence areas with more saline and cooler waters.

In conclusion, this study provides information about the composition and distribution of fish fauna in the northern Alboran Sea, an interesting area since it represents a transition zone between the Atlantic Ocean and the western Mediterranean Sea. The observed four fish assemblages on the continental shelf and slope seem to be strongly linked to the depth gradient. The comparison of our results with similar studies carried out in other Mediterranean areas shows the greatest differences below 500 m. Geographic comparisons along the northern Alboran Sea highlight some areas with major similarities basically below 200 m. Longitudinal differences on the fish assemblages occur in the inner shelf assemblages

(< 100 m) between Punta Entinas–Cabo de Gata and the remaining locations, due to differences in the distributional range of certain fish species (e.g. *C. aper, M. scolopax, S. smaris*). It is necessary to carry out multidisciplinay research in order to relate the observed patterns to environmental variables and trophic factors that are probably affecting the dynamics of these fish assemblages.

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